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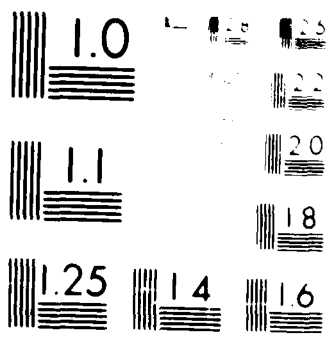
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[illegible] experiments provide support for the idea that express saccades are overt signs [illegible] of covert attention at a particular location. They provide no support for the idea that the subject must first disengage from the cue before express [illegible] occur. Our studies support a functional linkage between covert shifts [illegible] and the eye movement system. It is comforting to see that covert mechanisms [illegible] in the subject's overt orienting behavior in the form of efficient [illegible].

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SPEED OF COVERT ORIENTING OF ATTENTION

AND EXPRESS SACCADES

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Speed of Covert Orienting of Attention and Express Saccades 1.

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Abstract

Unusually fast saccades have been found in monkeys and humans following removal of a fixation stimulus (Fischer & Ramsperger, 1984). Recent studies suggest that the direction of covert attention is an important condition to produce express saccades. We confirm this idea by showing that the removal of the fixation stimulus interacts with cues about the likely location of the target. These studies support the view of a strong functional connection between covert orienting of attention and eye movements.

1. This paper was presented to the Psychonomics Society, *November 1986 in New Orleans. The research* was supported by contract N00014-86-K-0289 from the Office of Naval Research.

At the last several few meetings of the Psychonomics Society I have presented studies involving covert orienting of attention. These studies involve demonstrations that the speed of responding to targets on one side of the visual field is faster when attention has been cued to that location than when it has not. I have tried to break down the act of covert orienting into subcomponents including: disengaging attention from its current focus, movement of attention, and engaging attention at the target location. Studies with neurological populations have suggested that these components are computed at widely disparate sites. We have associated disengagement of attention with parietal lobes, (Posner et al, 1984), the movement of attention with midbrain (Posner et al, 1982) and have some evidence that the engagement of attention may be related to the pulvinar.

A number of years ago (Posner, 1980), I attempted to develop a relationship between covert orienting of attention and eye movements. I argued then that the two systems were functionally interrelated, even though one could move attention without moving the eye and under some conditions, could move the eyes while maintaining attention or even shifting it in the opposite direction.

In the last several years, a group of investigators in Germany have been presenting data on saccadic latencies following offset of the central fixation stimulus (Fischer and Bach, 1983) . (Fischer and Rasburger, 1984; Mayfrank, Mobashery, Kimmig, and Fischer, 1986). Under conditions when the central fixation stimulus is extinguished 200 msecs prior to a target appearing for a saccadic eye movement, they found that monkeys and human beings produced a number of eye movements that occur at very low latencies between 75 and 100 msecs (Figure 1). Since there is uncertainty in some of these conditions about which side of the fixation point the target will occur, it seems unlikely that these could be due to anticipations alone. Instead they argue that in the absence of a fixation stimulus, the subject is able to produce what they call "express saccades". In the monkey these have a modal latency of about 75 msecs and in the human being a modal latency of about 100 msecs.

FIGURE 1

These express saccades can be distinguished from longer saccades with modal reaction times of about 200 msecs that occur even in the presence of a fixation stimulus. The authors argue that removal of the fixation stimulus provides a sufficient condition for these very rapid eye movements.

Recently, this group of investigators proposed that extinguishing the fixation stimulus may not be a necessary condition for express saccades. If the subject's attention is first cued to the location of the target and then released from that cue, they find express saccades even when the fixation stimulus remains present in the visual field. These findings led the authors (Mayfrank, Mobashery, Kimmig, and Fischer, 1986) to argue that express saccades depend upon 1) orienting of attention to the location of the target, and 2) disengaging attention from the cue.

Figure 2

It seemed to us even prior to this latest publication that there must be close interrelationships between covert attention and express saccades. Indeed we (Posner, Nissen, & Ogden, 1978) had shown that eye movements toward targets at expected locations were very fast in comparison to uncued or unexpected locations even under conditions where information remained present on the fovea. To investigate this issue further we set up conditions in which we either turned on or turned off a fixation stimulus, and after a varying interval (determined randomly) presented a target six degrees to the left or right of fixation. The subject's task was to tap a single key in response to the target and irrespective of the location of the target. These are the usual conditions in which we have studied orienting of attention to cues. We expected to find, if there is a close relationship between the removal of the visual fixation and orienting of attention, faster reaction times in the absence of a fixation stimulus than in its presence. Since the subject either saw the the onset or the offset of the fixation stimulus at the start of the trial, the temporal predictability seemed to be equivalent to the two conditions. The data we obtained are shown in figure (3) Removal of the fixation stimulus produces systematically faster reaction times than its presentation at all target intervals. Similar rates of change of reaction time following both cue conditions argue that roughly similar alerting effects are obtained in the two conditions.

FIGURE 3

We now wished to see whether the advantage found without a fixation stimulus was due, to orienting attention. To do this, we crossed our manipulation of fixation stimulus with the presentation of cue events in the form of brightening one of two peripheral boxes located six degrees to the left or right of fixation prior to the presentation of the target. This is a standard way of creating cued and uncued targets. In our first experiment the probability of the target occurring on the cued side was .5 and the probability of the target occurring on the uncued side was also .5. In 30% of the trials no cue was presented in order to attempt a replication of the no cue conditions presented in the previous experiment. Under all conditions the fixation point was either presented or removed half a second before the initial cue and following the cue there was a target either 100 msecs or 800 msecs later. The cue remained present until the subject responded. The results are shown in Figure 4.

FIGURE 4

We replicated this experiment with a fresh population of twelve subjects at Washington University. The only difference in the experiment was that the target appeared on the cued side 80% of the time and on the uncued side 20% of the time. This was to allow us to obtain the advantage of cued over uncued trials even for the longer 800 msec interval. We found a significant effect of cue validity and a significant effect of the presence versus absence of a fixation stimulus and the two interacted such that the effect of fixation removal was larger in the invalid trials than in the validly cued trials. The invalid trials had longer RTs than the valid trials even at 800 msecs, presumably because the subject is induced to keep attention on the cued side because of the advantage in probability.

FIGURE 5

These two experiments provide general support for linking of express saccades to covert shifts of attention. When fixation is extinguished, thus producing conditions under which express saccades occur, we find faster shifts of covert attention to the target. When the fixation condition is crossed with cuing the subject to the target location, the effect of the presence of the fixation is reduced on valid trials when attention is thought to be already at the target location. If express saccades were due [illegible] to covert shifts of attention, we would expect to have the effect of fixation eliminated entirely on valid trials.

However, even on valid trials there does remain a residual effect of fixation. Whether this is due to a failure to draw the subject's attention to the cued location on some trials, or whether it represents a failure of covert attention to control express saccades completely we do not know.

In their recent work (Mayfrank, et al 1986), the German group has proposed the idea that express saccades not only require the subject to orient attention toward the target location, but also do not occur unless the attention was released from the cue. They suggest that the subject must be disengaged at the target location before express saccades occur. This seemed unlikely to us in view of our idea that attending to a cued location is the appropriate condition to produce very effecient movements of the eyes. Morrison, (1984), in his discussion of eye movements during reading, has argued that covert shifts of attention might facilitate the movement of the eyes found during reading. Obviously, if it was necessary to disengage attention at the cued location before facilitating eye movements, attention shifts would be unlikely to have application to reading. However, there is a confound in the Mayberry, et al experiment. The conditions in which they removed the location cue also provided the subject with a 200 msec warning signal before the target was presented. In the conditions where the cue remained present, no such warning signal was given. Thus, it seemed quite likely that the advantage in express saccades found with the removal of the cue was due to a more optimal warning interval.

To test this idea we presented a cue either for 50 msecs (brief) or until the subject responded (long). Target events were were presented at the cued or uncued locations either 150 msecs from the onset of the cue or 850 msecs from the onset of the cue. Whether the cue was turned off or left on the subject had the same warning interval about the occurrence of the target. In all cases, 500 msecs before the cue was presented either the fixation was turned on or turned off, as in the previous experiments.

In this experiment, there was no main effect of the fixation presence on reaction time. Perhaps this was because of the much greater complexity of the experiment than the previous ones. There were however, very significant main effects of cue condition and of the length of the cue and these two conditions interacted. The effect of cue condition was identical to what we have seen previously. The effect of cue length was to produce faster reaction times for the brief cue than the longer cue. This advantage of the brief signal depended very heavily upon the cue condition. In valid conditions, there was no advantage of the brief over the long cue whereas in invalid conditions there was a very clear advantage. This interaction is shown in Figure 6. The

results indicate that under valid conditions it makes no difference whatsoever to covert attention whether the cue is brief or long.

FIGURE 6

If this result applies to express saccades it would mean that the probability of express saccades when attention is at the target does not depend on whether the subject is engaged by the cue or not. It suggests that the results obtained by Mayberry, et al were due to alerting effects rather than cuing effects. In invalid conditions there is a very powerful effect of cue length, with a long cue making it more difficult to disengage to move to a new location.

Conclusions:

These experiments provide support for the idea that express saccades are overt signs of presence of covert attention at a particular location. They provide no support for the idea that the subject must first disengage from the cue before express saccades can occur. Our studies support a functional linkage between covert shifts of attention and the eye movement system (Posner, 1980). It is comforting to see that covert mechanisms can produce changes in the subject's overt orienting behavior in the form of efficient eye movements.

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Figure 1: I Distribution of saccade latencies for a unidrectional saccade following fixation offset. First mode is at 100 msec and represents express saccades. Second mode at 160 msec represents regular saccades.

II Distribution of saccade latencies for bidirectional saccades following fixation offset. First mode is at 120 msec and represents express saccades and second mode at 166

All data from Fischer & Ramsperger, 1984

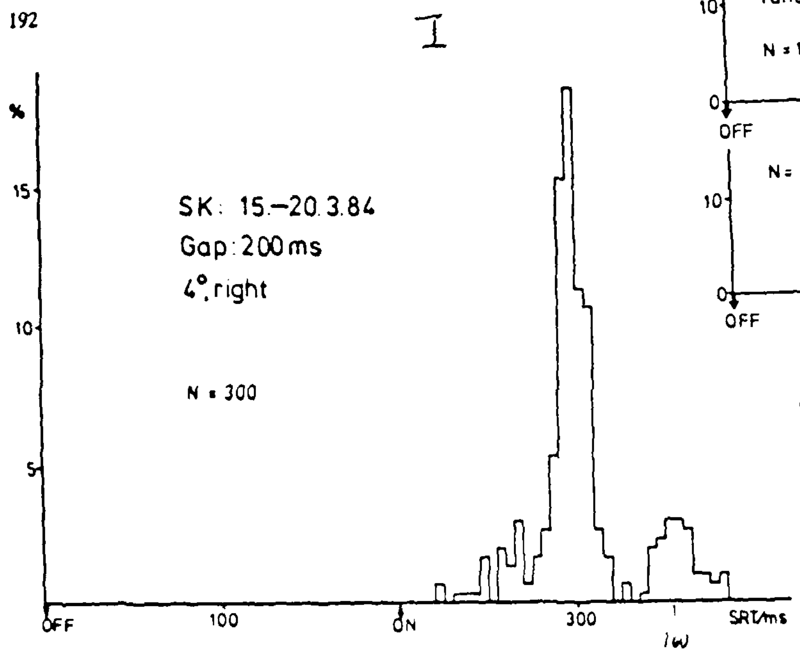
Figure 2: Mean latencies of hand (motor) and eye (visual) movements when the subject is cued to the target area (valid), uncued, or miscued (invalid) (Posner, Nissen and Ogden, 1978). The valid eye RTs are not far from the range of express saccades.

Figure 3: Mean reaction time as a function of cue to target interval for fixation onset and offset warning conditions. Data are for eight subjects.

Figure 4: Reacton time as a function of cue condition (null = no cue) for fixation on (solid) and fixation off (dotted) with cue to target intervals of 100 and 800 msec. Targets occur on the cued side (valid) with probability .5 and on the uncued side (invalid) with probability .5. Data are for twelve subjects.

Figure 5: Reaction time as a function of cue condition for fixation on (solid) and off (dotted) conditions with cue to target intervals of 100 and 800 msec. Targets occur on the cued side (valid) with probability .8 and on the uncued side (invalid) with probability .2. Data are for 12 subjects.

Figure 6: Reaction time as a function of cue condition for brief cues and for long cues. Data are for 16 subjects.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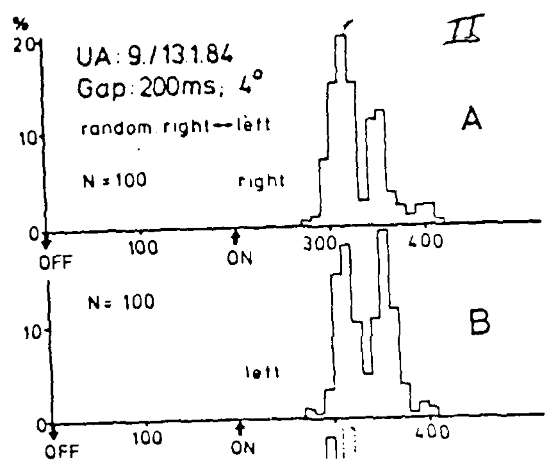
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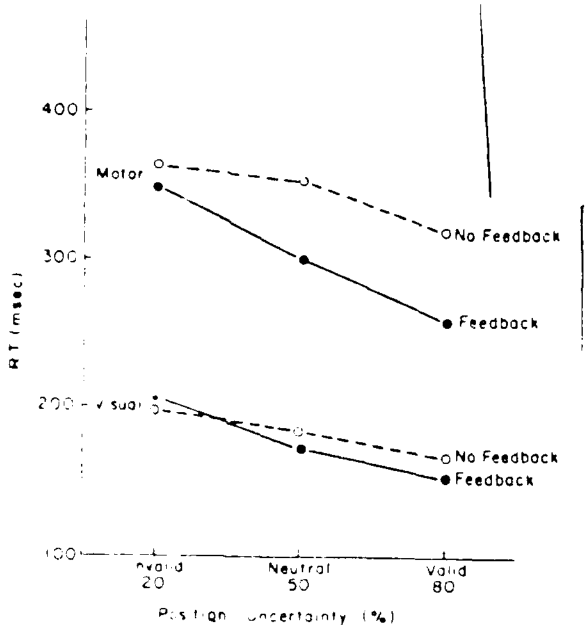
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100
RT (msec)
Motor
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Feedback
No Feedback
Feedback
Neutral
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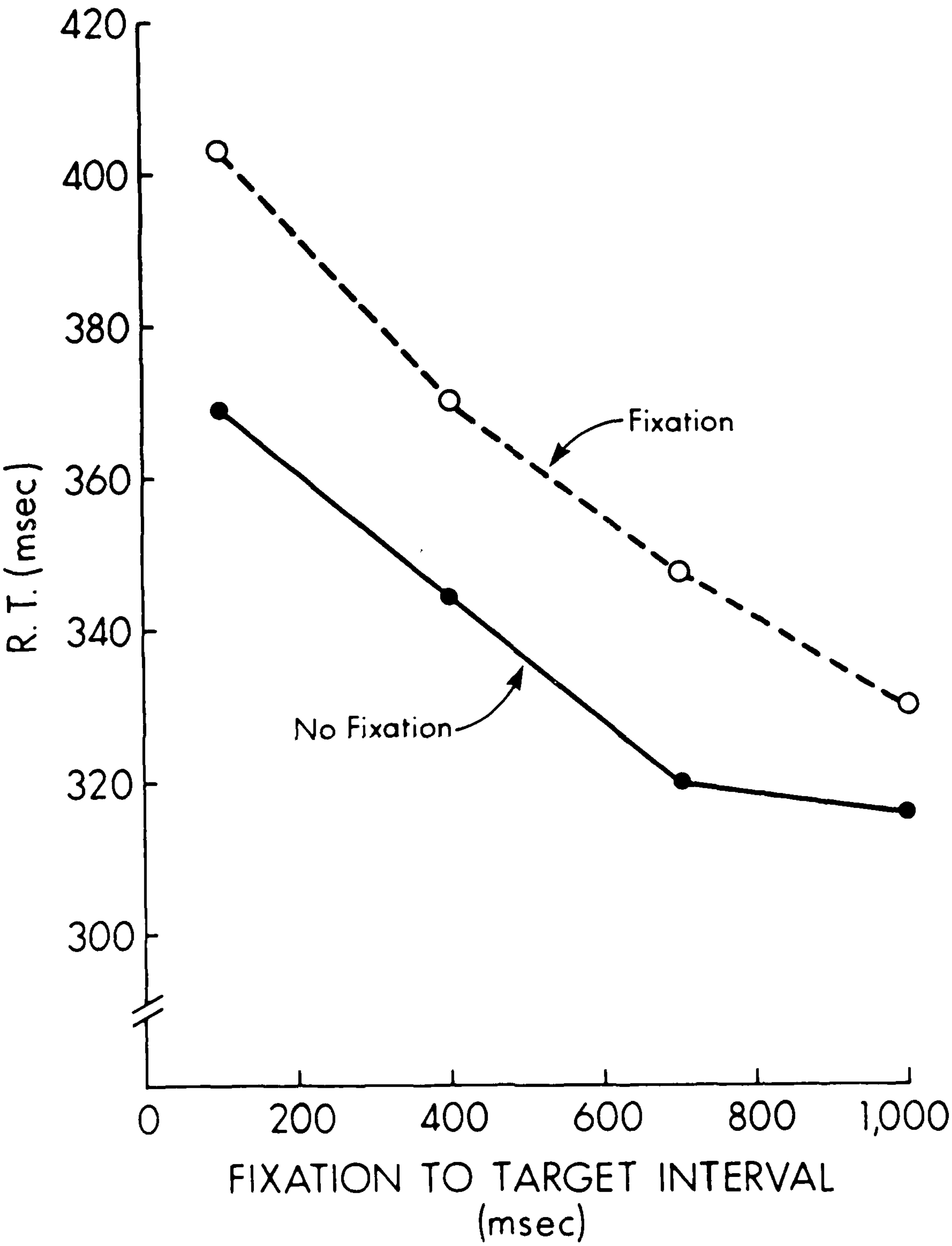
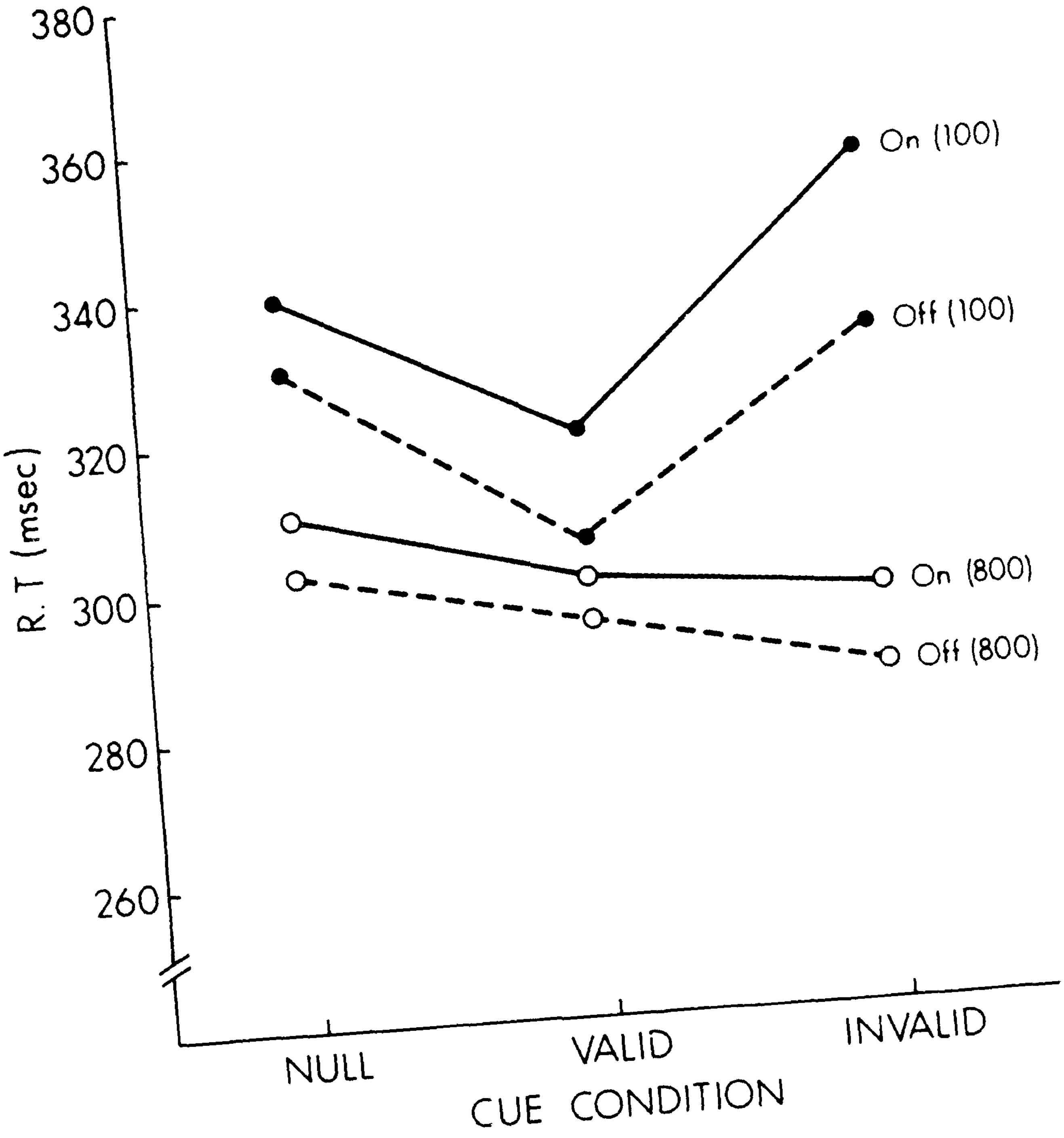
Valid
80
20



420
400
380
360
340
320
300
R. T. (msec)
Fixation
No Fixation
0
200
400
600
800
1,000
FIXATION TO TARGET INTERVAL
(msec)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360
340
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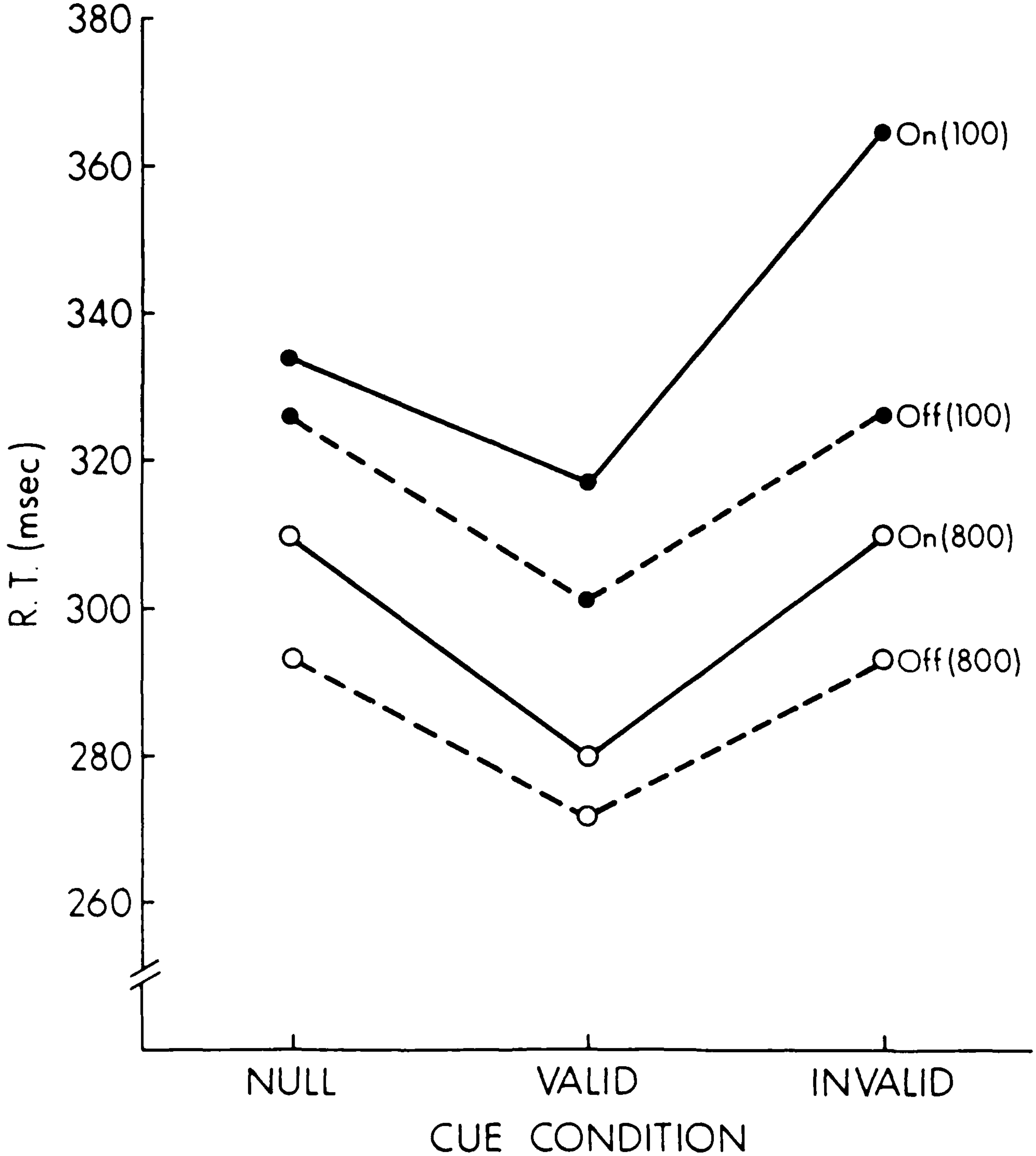
260
R. T (msec)
On (100)
Off (100)
On (800)
Off (800)
NULL
VALID
INVALID
CUE CONDITION



380
360
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R. T. (msec)
On(100)
Off(100)
On(800)
Off(800)
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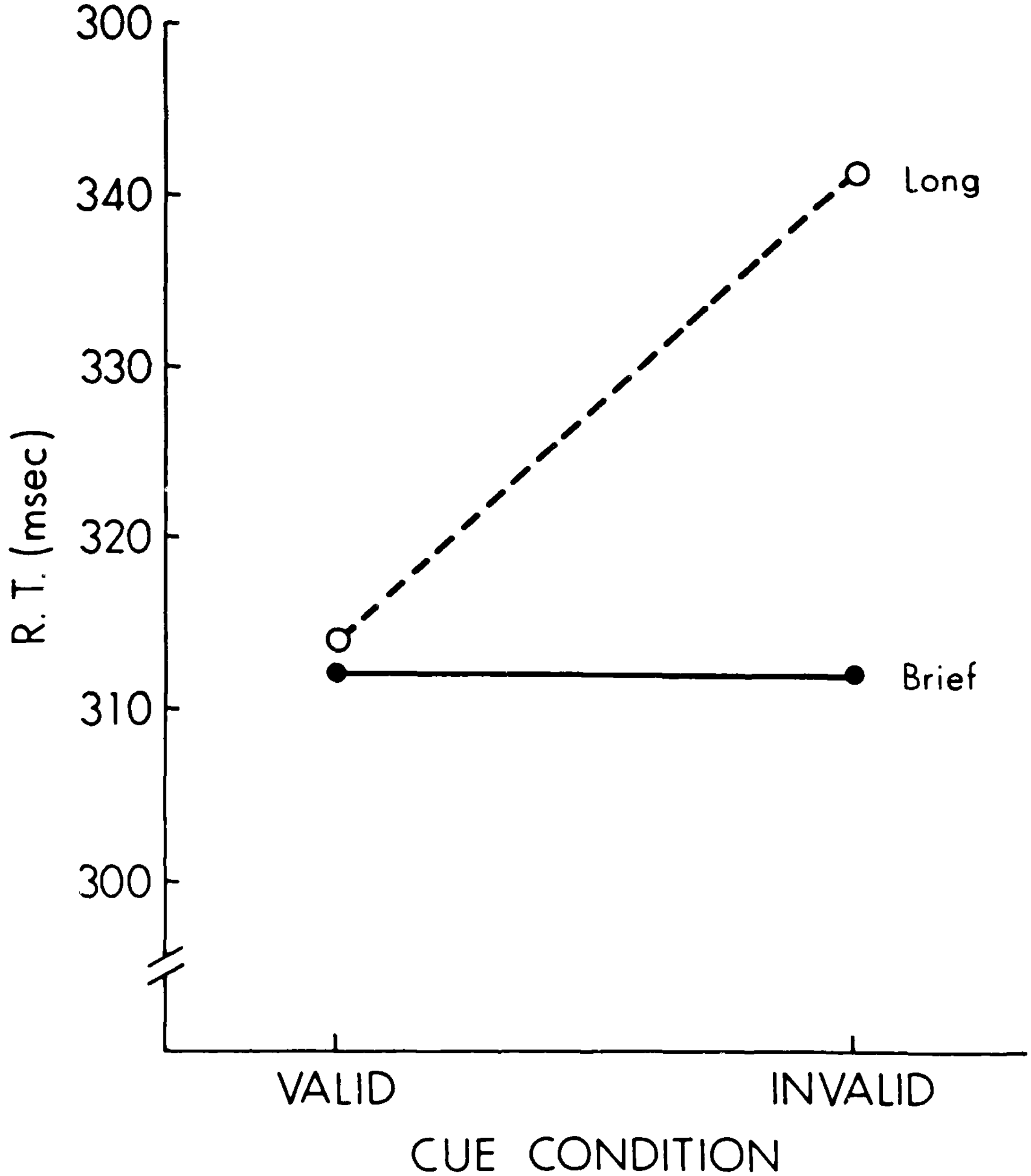
VALID
INVALID
CUE CONDITION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R. T. (msec)
Long
Brief
VALID
INVALID
CUE CONDITION

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